

The Issues of Developing UAVs at the Air Force Institute of Technology, and Those of Certification Problems

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ABSTRACT

One of the lines of research conducted at the Air Force Institute of Technology in Warsaw, Poland, is research into possible applications of the unmanned aerial vehicles (UAVs). The Institute's team has developed a whole family of UAVs to give training to the air defence troops. They are successfully used on military ranges. The Institute takes up efforts to find applications which under conditions typical of Poland can effectively satisfy needs of the Polish Armed Forces. The surveillance - and reconnaissance - dedicated issues prove to be of great significance in both war- and peacetime to provide e.g. the ground-based artillery with training. Another question is that of applying UAVs of different classes to meet the needs of civilian services, e.g. to patrol fire-affected areas, forests, state borders, etc.

The paper has been intended to deliver an overview of primary tasks of the UAVs, similar to those conducted world-wide, but with emphasis put on conditions typical of Poland, under which different Services and civilian organisations are expected to act. It also touches issues encountered by AFIT UAV R&D team while introducing new kinds of UAVs into service.

1.0 INTRODUCTION

Aerial targets have been designed to give training to the missiles-launching troops, the artillery, the navy, and the air force in both anti-aircraft guns firing and launching surface-to-air guided missiles, as well as firing aircraft guns and launching air-to-air missiles.

The objective of aerial-target systems is to simulate how an aircraft performs while in the air, to transmit and analyse results of firing the weapons, and to achieve possibly low cost of training the troops to fight aerial targets. The aerial targets operated nowadays world-wide can be classified into the following groups, according to type:

- a) towed targets,
- b) free-flight targets,
- c) free-fall targets (e.g. parachute-dropped),
- d) rocket aerial targets
- e) targets moving along ballistic curves.

At present, the rocket aerial targets and the free-falling ones are widely used in Poland for the training purposes. They do not, however, provide training in fighting low-flying, manoeuvring aerial targets. This hinders the training conditions from being fully representative of the actual modern battlefield. They do not contribute to improvement in cost effectiveness of the training process, since the effective time of

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fighting the targets is too short. Applications of remotely controlled, unmanned aerial vehicles is supposed and expected to fill the gap while giving firing-range training to the troops of the Polish Armed Forces, improve effectiveness thereof, and hence, to bring training methods used in the Polish Armed Forces closer to those of the NATO forces.

2.0 EARLY EFFORTS – TOW TARGET SYSTEMS

The earliest efforts in the field of national training systems regarded the tow-target systems. First towing devices introduced into service were designed and developed at the Air Force Institute of Technology in the years 1963-65. These were electrically driven winches, built on the Il-28 aircraft, designed to unwind and then wind the towing line of a silhouette tow target ‘Gacek’ (‘Bat’). The earliest winch, the WH-300, was furnished with a reelable 300-m towing line of diameter 5.5 mm. The winch was a component of towing systems of the Lim and Il-28 aircraft, for use in firing the aircraft guns thereof. The successor, i.e. the WH-1500 winch, was developed for the ‘Gacek’ (replaced then with a sleeve target) towing system used for the firing of ground anti-aircraft guns. The towing line was 1500 m in length.

After the Il-28 had been withdrawn from service, i.e. in the years 1977-80, the WH-1500 winch was upgraded to fit the Jak-40 towing system and to take a towing line of 3000 m. The upgraded version of the winch was marked as the WH-3000-Jak (Fig. 1). Located in the passenger compartment of the Jak-40, it was designed for the sleeve-target’s line winding and unwinding. The winch was controlled by an operator from the system-specific station in the luggage compartment of the aircraft.

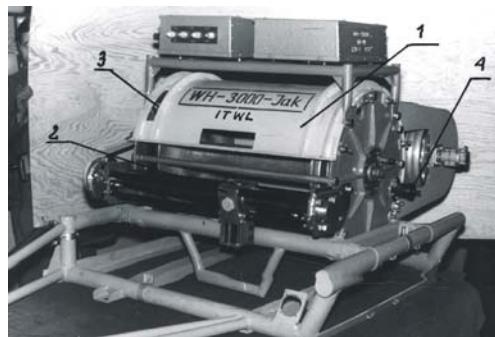


Figure 1: The WH-3000-Jak winch

At the same time, i.e. in the years 1976-78, designed and developed was the RZ-1000 winch (Fig. 2). It was an externally, i.e. under the An-2 fuselage, carried system to wind/unwind a 1000 m towing line with a sleeve target attached. The system was used for small-size weapons practice firing at low-flying targets. The winch was operated by a co-pilot, via a control desk on the left side of the aircraft cockpit.



Figure 2: The RZ-1000 winch

On the turn of the 1980s, the Jak-40 and the An-2 tow planes were withdrawn from service. Nowadays, there is no airplane in Poland of flying qualities that enable the towing of aerial targets in a way as to provide effective gunnery practice. Therefore, a decision has been taken at the Institute to suspend activity in this field until such an aircraft proves available in Poland.

Both severe demand in the armed forces for this kind of training, and technological progress have somehow enforced development of a kind of research, i.e. on the unmanned aerial vehicle systems serving as aerial targets.

3.0 UNMANNED AERIAL TARGETS

3.1 At the Air Force Institute of Technology – The Beginnings

Since the very beginning of the 1990s, work has been carried out at the Air Force Institute of Technology on capabilities of adapting the unmanned aerial vehicle (UAV) to serve as an aerial target. The scope of work has always included the following issues:

- a) analyses of aerodynamic systems of the UAV,
- b) take-off and flight control systems,
- c) payload.

Analytical results have pointed out to the problems that need to be solved to develop an efficiently performing system of operating such vehicles. Such a system should be well-suited to conditions of a firing range where troops are provided with training (specific terrain conditions, conditions for performing gunnery practice, evaluation of the training, the variety of firing agents in use, operating conditions imposed by the range infrastructure).

Theoretically, both sea and land ranges throughout Poland could be used to provide the troops with gunnery practice in firing at aerial targets. The reality is, however, different. Land ranges are not used because of too small dimensions thereof, and fire hazards. The only range that offers suitable conditions for such training is the sea range in Ustka, in the midst of Poland's coastline. Dimensions of this range are, approximately, 40 x 30km. Taking account of the necessary safety zones, there is only a small area for firing practice. These limited training capabilities have switched the Institute's interests to the development of small-size aerial targets.

3.2 Unmanned Aerial Vehicle FALCON

The first small-size aerial target design was the UAV 'FALCON' (Fig. 3). It was a short-range low-level aerial target, the first experimental - to some extent - vehicle designed for testing both flying qualities of aerial vehicles of such a class, and capability to apply a television-command system to guide it.

The FALCON aerial vehicle was a vehicle remotely piloted by an operator from the ground-based station. Fuselage of this vehicle had been designed in the flying-wing configuration, and of mixed composite-and-wood structure. For making landings, it was originally furnished with a two-wheel shock-absorbing landing gear replaced then with a skid landing gear. The take-off was performed from a bungee launcher. The airframe contained the remote-control system and the real-time TV-image transmitting system. A towing sleeve and flares (i.e. light emitters) or tracers made up the payload and were intended to provide better visual tracking capability. The FALCON was power-driven with a single-cylinder piston engine of the 4 KM rated power. The engine was an immediate source of power to drive a two-blade right-handed fixed-pitch propeller.

The FALCON was remotely controlled by an operator from a ground-based station, with remote-control device engaged. The remote pilot operated a manipulator equipped with control sticks and switches,

integrated with the 35 MHz transmitter. Actual positions of the control sticks and switches were given in the form of readouts by a processor-controlled electronic system of the manipulator and translated into the pulse-code modulated (PCM) FM signal. The effective service range of the remote-control unit was, approximately, 1 km.



Figure 3: The Falcon UAV

SPECIFICATIONS

Dimensions and weights:

Wing span	2.5 m
Length overall	1.3 m
Lifting surface	2.0 m ²
Max take-off weight	14.0 kg

Performance:

Max level speed	120 km/h
Min flying speed	40 km/h
Max endurance	30 min
Service ceiling	300 m
Mission radius	1000 m

The airplane was used on frequent occasions to test the payload for different applications. It crashed in the year 2000.

3.3 Unmanned Aerial Vehicle WAMPIR (Vampire)

The unmanned aerial vehicle WAMPIR (Vampire) was a new concept in this field (Fig. 4). It was remotely controlled by an operator (pilot) from a station on the ground. The flying-wing airframe of the composite-and-metal structure was power-driven with a four-cylinder two-stroke piston engine with a pusher propeller and later on, after modifications due to flight-test results, with a pull propeller. The vehicle was furnished with a single-wheel shock-absorbing landing gear used only while making a landing. The take-off was performed from a bungee launcher, earlier used for the FALCON UAV. The airframe contained the remote-control system and the real-time TV-image transmitting system.

The aerial vehicle WAMPIR was power-driven with a two-stroke four-cylinder piston engine 3W-240 B4 of 18 KM rated power. The engine was immediately driving a pusher propeller, and later on - a fixed-pitch pull propeller.

A ground-located operator controlled the WAMPIR by means of a remote-control manipulator. The operator handled the manipulator equipped with control sticks and switches and integrated with the 35 MHz transmitter. The readings of current positions of the control sticks and switches were given by the manipulator's processor-controlled unit to be then converted into the pulse-code modulated (PCM) FM signal. The signal was received with the airborne receiver to be then converted to provide real-time control of servo-mechanisms which drive control surfaces and other control components. The battery that powered the target drone's controls was common to both the receiver and the servos. The remote-control system's effective service range was approx. 1 km.



Figure 3: The WAMPIR UAV

SPECIFICATIONS

Dimensions and weights:

Wing span	3.00 m
Length	1.75 m
Lifting surface	2.29 m ²
Weight, empty	37.00 kg
Max take-off weight	48.00 kg

Performance

Max level speed	160 km/h
Min flying speed	70 km/h
Max endurance	1 h
Service ceiling	500 m
Mission radius, approx.	1000 m

Because of short-range operation and lack of capability to perform long-lasting flights, the decision has been made to come back to earlier concept of the aerodynamic configuration.

3.4 Unmanned Aerial Vehicle CHRABASZCZ (May-bug)

The objectives of the designers while developing a new UAV were as follows:

- To provide capability of easy transportation of: aerial targets, means of operating them, testing equipment and training aids,
- To provide capability to perform take-offs and landings despite terrain conditions (optionally, parachute landing capabilities),

- To minimise the number of operators to two,
- To furnish the aerial targets with devices to tow sleeve targets 5.6 m in length and 0.45 m in diameter,
- To provide capability to carry externally - on three underwing hardpoints - and supply with power special-purpose stores (flares, smoke generators, IR emitters, cameras, sensors, etc.),
- To apply the PC-based simulation program to provide aerial-target operators with practice (training); the program would be based on a model of dynamics of the aerial target in use,
- To provide aerial-target operators with practice (training) under actual conditions - via control desks in the master-slave configuration.

What resulted was an aerial target CHRABASZCZ (May-bug), designed for providing the troops with range training in the firing of portable launchers, anti-aircraft artillery and rifled weapons at aerial targets.



Figure 5: The CHRABASZCZ UAV

SPECIFICATIONS

Dimensions and weights:

Wing span	3.02 m
Length overall	2.42 m
Max take-off weight	18 kg

Performance

Max level speed	220 km/h
Min flying speed	70 km/h
Max endurance	120 min
Mission radius, approx.	3000 m

Remote control – assisted with optical guidance

Payload: optical, infrared, and radar means of target imagery.

Experience gained in the course of testing this target has enabled the target designers to address the air (antiaircraft) defence forces with the concept of building a complex aerial-targets system.

3.5 The System of Guided Manoeuvring Aerial Targets

The system of guided manoeuvring aerial targets has been designed to provide the troops with firing practice to fight low-flying means of air attack and air reconnaissance (helicopters, unmanned aerial

vehicles). It also has been intended to give training in intercepting, tracking and fighting these means of attack/reconnaissance with antiaircraft gunnery under firing-range conditions.

Development and manufacture of the system followed with a complete cycle of tests have enabled accomplishment of the above-mentioned tasks. The system comprises the following items:

- a) single-use (non-recoverable) aerial target KOMAR (Mosquito),
- b) recoverable aerial targets SZERSZEN (Hornet),
- c) ground-based hardware to provide transport, take-off, and control over aerial targets while in the air.

The system was introduced into service with the Polish Army in 2006.

Designs of the above-mentioned aerial targets have been based on the ‘flying wing’ concept that best meets requirements for handling-and-tactical qualities, as well as performance-oriented and operational requirements. As far as the UAV-dedicated structural configuration is concerned, there are a variety of solutions in use worldwide.

Selection from a range of them often depends on the kind of mission the UAV is expected to perform. However, the ‘flying wing’ design has recently become the more and more often selected solution. From the standpoints of the manufacturing process and airborne equipment, the single-use system to be destroyed (KOMAR) has been optimised to minimise costs of production and operational use. The recoverable UAV SZERSZEN is featured with better speed and endurance characteristics and greater payload variety.

Both the targets take off from the ground-based launchers to be then remotely controlled by a surface-grounded operator. Flight control is assisted with an optical surveillance system. Recovery of the aerial target KOMAR, if not destroyed, is also possible - by means of the aeroplane-like landing. The recoverable targets SZERSZEN are capable of performing aeroplane-like landings or optionally, i.e. in emergency, being parachuted.

3.5.1 Aerial-Target Simulator KOMAR (Mosquito) Simulator

This is a simulator of the single-use aerial target KOMAR (Fig. 6) used to provide training in launching rockets from portable launchers. The target has been intended to be destroyed with antiaircraft rockets launched at it.

The simulator comprises:

- a) IR emitters (two (2) on wingtips, time of operation – 60 s each),
- b) Smoke generator,
- c) Radar reflector (optionally).

This simulator can be additionally furnished with a parachute landing system.



Figure 6: Single-use (non-recoverable) aerial-target simulator KOMAR

SPECIFICATIONS

Configuration	flying wing
Wing span	2.2 m
Length overall	1.5 m
Max take-off weight	15 kg
Carrying capacity	3 kg
Max level speed	170 km/h
Min flying speed	60 km/h
Cruising speed	120 km/h
Rate of climb	8.4 m/s
Range	3000 m
Endurance	1 h

Take-off – bungee launched

Recovery - belly landing or parachute

3.5.2 Aerial-Target Simulator SZERSZEN (Hornet)

This is a simulator of the recoverable aerial target SZERSZEN (Fig. 7) used to provide training in the intercepting and tracking of the low-flying manoeuvring targets, and then fighting them with antiaircraft rifled weapons.

The simulator SZERSZEN has been furnished with:

- sleeve-target system with acoustic hit recorder,
- radar reflector,
- parachute-landing system,
- IR emitters (optionally).

The acoustic hit recorder co-operates with the firing data transmission system and ground-station display unit.

While in the air, the sleeve target is automatically unwound in response to the control command emitted from the surface grounded control station. The radar reflector with its 3 m^2 signature can be towed as located before the sleeve target.



Figure 7: Recoverable aerial-target simulator SZERSZEN

SPECIFICATIONS

Configuration	flying wing,
Wing span	3.1 m
Length overall	1.8 m
Max take-off weight	25 kg
Carrying capacity	10 kg
Max level speed	170 km/h (140 km/h with a sleeve target attached),
Min flying speed	80 km/h
Cruising speed	120 km/h
Rate of climb	8 m/s
Range	3000 m
Endurance	2 h
Take-off - launcher-effected	
Recovery - the belly skid landing, or parachuted	

3.5.3 Guidance and Flight Control Station

The guidance and flight control station has been designed for performing tasks with the aerial targets SZERSZEN employed, according to the pre-planned parameters of flight profile, with no need of direct target observation.

The guidance and flight control station has been organised and located in the thermally insulated, mobile compartment, and based on real-time data transmission systems. Information that comprises:

- flight data (speed, altitude, attitude angles, power plant parameters),
- navigational data (GPS-delivered fix(es), heading, flight path, extrapolated flight-path plot),
- mission-specific data (parameters of a tow target, recorded hits),

is displayed on the computer display unit, close to the colour airborne flight-heading-adjusted CCD camera. The displayed information is used by the operator to control the aerial target: whether it moves according to the pre-planned parameters of the mission (the subsequent stages thereof) and to real-time modifications, according to commands and instructions by the practice commander. Fig. 8 illustrates the ways of displaying this information.



Figure 8: Visualisation of flight data on the guidance and flight control station

3.5.3.1 Immediate Evaluation of Firing Effects

The immediate firing-effects evaluation systems find their applications in aerial-targets towing systems (sleeve and point targets), intended to provide air and ground antiaircraft gunnery practice. They record numbers of projectiles passing close to the target to transmit then the recorded data to the surface-grounded station or to the aircraft towing the target. Hence, they provide immediate evaluation of firing effects by means of displaying them on the firing station. The guns are fired at a sleeve target towed by the recoverable unmanned aerial vehicle SZERSZEN.

3.5.4 Ground-Based Facilities

The ground-based facilities included into the system have been intended to ensure operation to the two above-mentioned types of manoeuvring aerial targets KOMAR (Mosquito) and SZERSZEN (Hornet), i.e. transportation, storage, servicing, and operational use (the taking-off, mission flying, landing, and flight-readiness recovery).

An integrated transport/take-off stand is a ground-based hardware item of the guided manoeuvring aerial-targets system. The stand, designed for aerial-target transportation, has been additionally equipped with systems, devices and assemblies necessary to operate aerial targets: pre-flight servicing, the taking-off, flight control and transportation for post-mission servicing/maintenance, and social facilities for the staff (operators).

These ground-based facilities include:

- a) means of transport of aerial targets and necessary equipment, being a take-off/flight control platform and the mount for antennas of the target guidance/flight-control system; also, a mount for the take-off platform,
- b) a take-off launcher – a pad that would enable the aerial vehicle take-off, i.e. it provides the required initial (take-off) speed with energy of stretched bungees used,
- c) a guidance/flight-control station,
- d) an optical flight-control station - a self-standing system that enables the operator to perform the task with the object's 'being visible' with optical means of observation (field glasses),
- e) an electric power supply system,
- f) maintenance-dedicated equipment, i.e. a maintenance kit that provides: pre-flight maintenance of the aerial target and its payload, post-flight transport, and minor repairs and overhauls,
- g) equipment (social facilities) to support staff (operators) under field conditions.

3.6 Aerial-Target Simulator Turbo KOMAR (Turbo Mosquito)

The system of guided manoeuvring aerial targets mentioned above and introduced into service in 2006 has satisfied the needs of training both anti-aircraft gunners and portable rocket launching soldiers. However, it does not provide necessary parameters to train crews of vehicle launched surface-to-air missiles.

In order to fill the existing gap AFIT's UAV Research and Development team designed and tested a new kind of vehicle – the jet engine powered Turbo KOMAR. Similar to previous designs it has been intended to start from the catapult - bungee or pneumatic (under development). The new system is intended to fly under fully autonomous control.



Figure 8: High speed jet powered aerial-target simulator Turbo KOMAR

SPECIFICATIONS

Configuration	classic
Wing span	2.04 m
Length overall	2.25 m
Max take-off weight	20 kg
Max level speed	370 km/h
Min flying speed	80 km/h
Range	20 km
Endurance	20 min

Take-off - launcher-effected

Recovery – parachuted, belly landing in case of emergency

4.0 MINI SURVEILLANCE UAV HOB-BIT

Besides constant development of aerial targets, AFIT's UAV R&D team intensively work on a mini UAV Hob-bit. The system was initially designed for collecting information by special forces. In the course of design and testing stages it evolved into a universal reconnaissance and surveillance system for military as well as civilian forces.

Hobbit is a small, fully composite, two electric engines driven airplane with ability to perform fully autonomous flight. The airframe was designed using advanced CAD systems. The tooling was made with the NC milling machines. Its fully modular design which enables quick replacement of the main battery

and installation of different nose payloads (i.e. IR sensors, digital camera, CCD camera). This vehicle interacts with a ground control station intended to pre-programme the flight path, to receive, record and display the UAV-transmitted data, and to monitor flight data in the course of a mission.

The vehicle is either hand, bungee or catapult launched. It can operate up to 1 hour. It's recovered by belly or parachute landing.



Figure 9: Hob-bit reconnaissance vehicle under development.

SPECIFICATIONS

Wing span	1.7 [m]
Length overall	1.2 [m]
Max take-off weight	5 [kg]
Airspeed range	35 – 90 [km/h]
Flight time	1 [h]
Operating radius	10 [km]
Take-off	hand, bungee or catapult launched
Recovery	classic or parachute

5.0 UAV CERTIFICATION ISSUES

Lack of appropriate regulations or institutions and executive acts in case of already existing regulations is a severe problem that limits development of UAV systems in Poland. It does not apply much to aerial targets, as tests and operations thereof are conducted within closed military areas, but it seriously limits development and practical usage of civil UAV systems. The authors don't know any existing regulations that allow using UAV systems in Polish civil controlled airspace. Also, there are no procedures for both the manned and unmanned vehicles to cooperate in such a way to minimize the risk of collisions (i.e. monitoring and early warning systems).

One of the objects of the AFIT's UAV R&D team while designing the miniature UAV system Hob-bit was to reduce the maximum take-off weight down to 5kg. It was the effect of Polish aerospace regulations, at present in force, which say that an unmanned aerial vehicle up to this weight limit is treated as a model and doesn't have to be certified to fly in the civil airspace. The above presented approach does not work in case of larger designs, of course. It shows an urgent need to establish regulations of using UAVs in

controlled civil airspace, especially in the range of altitudes between 1000m to 3000m, where „see and be seen” approach is of the utmost importance.

6.0 SUMMARY

Technological progress, so rapid over the last years, and increased accessibility to new solutions have both enabled development of all-new techniques of accomplishing a variety of tasks within a wide range of domains. These new technological solutions have provided either some rapid increase in the quality of performing the tasks or vital reduction of costs, with the comparable quality level maintained. It is worth remembering that the ‘unmanned aerial vehicles (UAVs)’ are nothing else but a new technique. Whether the new opportunities and already existing potentialities are well-used, depends - to a high degree - on how much determination there is to proceed with the projects based on such solutions.

Development of the above-mentioned systems also depends on legal regulations that allow the UAVs to be operated within the airspace of the country, as it is with the manned aircraft. The matter of preparing common requirements and regulations for the UAVs has become one of the most important issues to be dealt with by international working groups. AFIT representatives actively participate in proceedings of such groups. They are expected to prepare legal basis for certification of UAVs to provide safe operational use thereof within the airspace of the Republic of Poland. Suggested rules and regulations should comply with international documents.

7.0 REFERENCES

Non-published AFIT proceedings.

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